

# Journal

of Achievements in Materials  
and Manufacturing Engineering



Published monthly as the organ of the World Academy of Materials and Manufacturing Engineering

Editor-in-Chief Prof. Leszek A. Dobrzański

Volume 71 • Issue 2 • August 2015





## Editor-in-Chief

Prof. Leszek A. Dobrzański – Gliwice, Poland

## Editorial Council

### Deputies Editor-in-Chief

Prof. Emin Bayraktar – St-Ouen, France  
Prof. Tsanka Dikova – Varna, Bulgaria  
Prof. Anna Dobrzańska-Danikiewicz – Gliwice, Poland  
Prof. Yong Taek Im – Daejeon, South Korea  
Prof. Lothar Kroll – Chemnitz, Germany  
Prof. Cemal Meran – Denizli, Turkey  
Prof. Jerzy Pacyna – Cracow, Poland  
Prof. Maria Helena Robert – Campinas, Brazil  
Prof. George Totten – Portland, USA  
Prof. Jose Roberto Vargas Garcia – Mexico-City, Mexico  
Prof. Kanaka Durga Vara Prasad Yarlagadda – Brisbane, Australia

## Production Editor

Ms Marzena Kraszewska, MA, – Poland

## Associated Editors

### Technical Editor

Dr Małgorzata Dziekońska

### Text Editors

Dr Eugeniusz Hajduczek  
Ms Justyna Hajduczek-Jarka, MSc

## Thematic Area Editors

Prof. Marcin Adamiak  
Prof. Klaudiusz Gołombek  
Prof. Janusz Mazurkiewicz  
Prof. Marek Roszak  
Dr Wojciech Borek  
Dr Zbigniew Brytan

## Statistical Editor

Prof. Jarosław Żmudzki

## Language Editor

Prof. Piotr Malara

## Editorial Assistance

Dr Paweł Jarka  
Dr Ludwina Żukowska  
Ms Barbara Nieradka-Buczek, MSc  
Ms Magdalena Zorychta, MSc

## Reading Direct Editors

Dr Marek Sroka  
Mr Adam Jagiello, MSc

## Editorial Key Reviewers Committee

Prof. Sadek Absi Alfaro – Brasilia, Brazil  
Prof. Gilmar Batalha – Sao Paulo, Brazil  
Prof. Michal Besterci – Kosice, Slovakia  
Prof. Silvio Brunatto - Curitiba, Brazil  
Prof. Andrzej Buchacz – Gliwice, Poland  
Prof. Tara Chandra – Wollongong, Australia  
Prof. Dhanesh Chandra – Reno, USA  
Prof. Antonio Cuhna – Guimaraes, Portugal  
Prof. Elena David – Rm. Valcea, Romania  
Prof. Janusz Dobrzański – Gliwice, Poland  
Prof. Marek Dollar – Oxford, Ohio, USA  
Prof. Georgiy Drapak – Khmelnytsky, Ukraine  
Prof. Sabahudin Ekinović – Zenica, Bosnia and Herzegovina  
Prof. Renato Esposito – Naples, Italy  
Prof. Spilios Fassois – Patras, Greece  
Prof. Janez Grum – Ljubljana, Slovenia  
Prof. Toshio Haga – Osaka, Japan  
Prof. Abdel Magid Hamouda – Doha, Qatar  
Prof. Stuart Hampshire – Limerick, Ireland  
Prof. Marek Hetmańczyk – Katowice, Poland  
Prof. Hong Hocheng – Hsinchu, Taiwan  
Prof. Werner Hufenbach – Dresden, Germany  
Prof. David Hui – New Orleans, USA  
Prof. Leopold Jeziorski – Czestochowa, Poland  
Prof. Jerzy Jędrzejewski – Wrocław, Poland  
Prof. Ivars Knets – Riga, Latvia  
Prof. Janez Kopač – Ljubljana, Slovenia  
Prof. Borut Kosec – Ljubljana, Slovenia  
Prof. Antonin Kriz - Plzen, Czech Republic  
Prof. Piotr Kula – Lodz, Poland  
Prof. Karl Kuzman – Ljubljana, Slovenia  
Prof. Klaudiusz Lenik – Lublin, Poland  
Prof. Bogusław Major – Cracow, Poland  
Prof. Stanisław Mitura – Koszalin, Poland  
Prof. Andrew Nee – Singapore, Singapore  
Prof. Jerzy Nowacki – Szczecin, Poland  
Prof. Jose Luis Ocaña Moreno – Madrid, Spain

Prof. Abraham Ogwu – Paisley, United Kingdom  
 Prof. Peter Palček – Zilina, Slovak Republic  
 Prof. Fusheng Pan – Chongqing, China  
 Prof. Roumen Petrov – Zwijnaarde, Belgium  
 Prof. Mario Rosso – Turin, Italy  
 Prof. Stanislav Rusz – Ostrava, Czech Republic  
 Prof. Yuriy Shalapko – Khmelnytsky, Ukraine  
 Prof. Božo Smoljan – Rijeka, Croatia  
 Prof. Jerry Sokolowski – Windsor, Ontario, Canada  
 Prof. Mirko Soković – Ljubljana, Slovenia  
 Prof. Zinoviy Stotsko – Lviv, Ukraine  
 Prof. Shamsuddin Sulaiman – Serdang, Malaysia  
 Prof. Michał Szota - Czestochowa, Poland  
 Prof. Ming-Jen Tan – Singapore, Singapore  
 Prof. Eva Tillova – Zilina, Slovak Republic  
 Prof. Miklos Tisza – Miskolc, Hungary  
 Prof. Bekir Sam Yilbas – Dhahran, Saudi Arabia  
 Prof. Andrzej Wojciechowski – Warsaw, Poland  
 Prof. Emilia Wołowicz-Korecka – Lodz, Poland  
 Prof. Dagou Zeze – Durham, United Kingdom  
 Prof. Jie Zhou – Delf, the Netherlands  
 Prof. Marian Żenkiewicz – Bydgoszcz, Poland

## Patronage



World Academy of Materials  
and Manufacturing Engineering



Polish Academy of Sciences,  
Committee of Materials Science,  
Section of Metallic Materials



International Federation  
of Heat Treatment  
and Surface Engineering



Association  
of Computational Materials Science  
and Surface Engineering

## Financial support

In 2015 the publication of the Journal is financially supported by the Ministry of Science and Higher Education in Poland.

## Journal Registration

The Journal is registered by the Civil Department of the District Court in Gliwice, Poland at number 279.

## Abstracting services

This Journal is sent to individual receivers from ca. 50 countries of the world and is delivered to the National Libraries and Universities and also to other scientific institutions in ca. 50 countries of the world. The electronic system of Reading Direct allows to access to the electronic version of that journal on-line, in the promotional period free of charge. This Journal is included in the reference list of the Polish Ministry of Science and Higher Education (9 points). The Journal is cited by Abstracting Services such as:



The procedure of its registration in the databases of Scopus, Compendex, CiteSeer, GetCited, Web of science, Engineering Village, Public Knowledge Project, Edith Cowan University's Institutional Repository, Journals Online and Inspec has begun.

## Publisher



International OCSCO World Press  
ul. Zygmunta Starego 6/30  
44-100 Gliwice, Poland

e-mail: [info@archivesmse.org](mailto:info@archivesmse.org)

Bank account:

Stowarzyszenie Komputerowej Nauki o Materiałach  
i Inżynierii Powierzchni

Bank name: ING Bank Śląski

Bank address: ul. Zwycięstwa 28, 44-100 Gliwice, Poland

Account number/IBAN CODE:

PL7610501298100002300809767

Swift code: INGBPLPW

Gliwice – Campinas – Portland – Madrid – Daejeon – Brisbane – Cairo

© 2015 International OCSCO World Press. All rights reserved.

∞ The paper used for this journal meets the requirements of acid-free paper.  
Printed in Poland.



This journal is a part of Reading Direct, the free of charge alerting service which sends tables of contents by e-mail for this journal and in the promotion period also the full texts of papers. You can register to Reading Direct at

<http://www.journalamme.org>